

UNITED STATES PATENT APPLICATION

OF

NANG KON KWAN

FOR

CLIENT CONTROLLED DATA RECOVERY MANAGEMENT

06502.0336

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

Field of the Invention

The present invention generally relates to data processing systems, and more particularly, to digital certificates and the archival and recovery of encryption keys.

Related Art

5 With the advent of the Internet and the increasing use of large computer networks by millions of people world-wide, security against fraud becomes a paramount concern. Conducting business in the current e-commerce environment requires a level of security that can withstand intentional attempts by malicious hackers and imposters, as well as protect against accidental erroneous information  
10 due to unintentional technological errors. The ability to determine the correct identity of an online entity remains vital to e-commerce and many other computing environments, applications, and purposes. One such way of identifying online identities is through the use of digital certificates.

Digital certificates, or "certificates," are a form of electronic identification used  
15 by computers, analogous to, for example, a driver's license. They may be an attachment to an electronic message, and they attest that the issuing authority certifies that the data associated with the certificate, such as the email address of the certificate holder, is indeed accurate and trustworthy for the lifespan of the certificate. A certificate may be used for encrypting messages for the holder, and to  
20 verify signatures created by the holder. Digital certificates are described in detail in "Understanding Public-Key Infrastructure: Concepts, Standards, and Deployment Consideration," Carlisle Adams et al., New Riders Publishing (1999), and "Digital Certificates: Applied Internet Security," Jalal Feghhi et al., Addison-Wesley (1999)

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

which are incorporated herein by reference. Certificates provide a highly-secure, bi-directional security mechanism. Not only can individual certificate holders ensure that their emails and other messages are cryptographically secure, recipients can also authenticate the identity of a message's sender. In addition, users can verify the integrity of commercial web sites with which they perform transactions, and those same sites can use certificates to replace traditional username and password access control mechanisms.

For instance, username and password combinations are not secure. If someone steals a username and password, the thief can gain access to controlled data protected by the stolen username and password from anywhere in the world. Once a username and password combination has been compromised, the associated user cannot easily notify the corresponding access-controlled site of the problem. Also, user has to remember every unique combination of usernames and passwords for every access-controlled site with which he interacts.

Certificates are typically issued by Certificate Authorities ("CA") which are trusted third-party organizations or companies that issue digital certificates used to create digital signatures and public-private key pairs. The role of the CA in this process is to guarantee that the individual granted the unique certificate is, in fact, who he or she claims to be. For example, the CA may have an arrangement with a financial institution, such as a credit card company, that provides the institution with information to confirm an individual's claimed identity. CAs are an important component in data security and electronic commerce because they establish a chain

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-406-4000

of trust so that the two parties exchanging information can be sure they are really who they claim to be.

An individual wishing to send an encrypted message applies for a digital certificate from a CA. The CA issues an encrypted digital certificate containing the applicant's public key and a variety of other identification information. The CA makes its own public key readily available through print publicity or perhaps on the Internet. The recipient of an encrypted message uses the CA's public key to verify the digital certificate attached to the message, verifies it as issued by the CA and then obtains the sender's public key and identification information held within the certificate. With this information, the recipient can send an encrypted reply.

Generally, for signing, the signer uses a private key to sign a document or message, and the verifier use the public key of the signer to verify the document or message. For encryption, the sender uses the public key of the recipient to encrypt the document and sends it to the recipient. The document can then only be decrypted by the recipient's private key. Since the recipient is the only one who has the recipient's the private key, the document is protected during transit. Use of encryption, private and public keys are described in detail in "Understanding Public-Key Infrastructure: Concepts, Standards, and Deployment Consideration," Carlisle Adams et al., which was previously incorporated herein.

In conventional certificate management systems, the CA uses a certificate manager to sign and revoke certificates. The certificate manager also maintains a database of issued certificates so that it can track renewal, expiration, and

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

revocation of certificates. The certificate manager receives and responds to requests to authenticate an entity.

Conventional certificate management systems also have a registration manager to which the certificate manager delegates some certificate management functions. In particular, a registration manager performs tasks such as end-entity authentication and formulation of the certificate requests for the certificate manager. In this configuration, end-entities (e.g., users) register with the registration managers to obtain certificates. Each registration manager authenticates the end-entity for the certificate manager and requests a new certificate for the end-entity from the CA.

Another component of the certificate management system is called the data recovery manager. The data recovery manager archives user's encryption keys for the certificate manager. This way if an end-entity loses a private data-encryption key, the key can be recovered before any data that was encrypted with the corresponding public key can be read.

The data recovery manager stores encryption private keys automatically whenever the associated or connected certificate manager issues certificates to users. The data recovery manager stores encryption private keys in a secure key repository in its internal database; each key is stored as a key record. The archived copy of the key remains encrypted (or wrapped) with the data recovery manager's storage key which uniquely identifies the data recovery manager. It can be decrypted (or unwrapped) only by using the data recovery manager's corresponding private key, to which no individual has direct access. The data recovery manager typically indexes stored keys by key number (or ID), owner name, and a hash of the

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

public key, allowing for highly efficient searching by name or by public key. The data recovery manager uses its private storage key to decrypt and recover an archived key.

For security reasons, the data recovery manager typically is maintained by the CA, but the registration manager may be maintained outside the control of the certificate authority. Some organizations, however, are not comfortable with this conventional architecture because it relinquishes complete control over an organization's private key archive to the certificate authority.

### **SUMMARY OF THE INVENTION**

In accordance with the present invention, a method in a data processing system for requesting a digital certificate from a certificate authority and archiving an encryption key outside of the certificate authority is provided. The method comprises receiving a request from a user for a digital certificate. It further comprises receiving an indication of proof of archival of the user's encryption key associated with the request, wherein the user's encryption key is archived under control of an entity other than the certificate authority.

Furthermore, in accordance with the present invention, a method in a data processing system for archiving an encryption key by an entity other than a certificate authority is provided that comprises receiving an encryption key for archiving, and archiving the received encryption key. The method further comprises creating an indication of proof of archival of the received encryption key and sending the indication of proof of archival.

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N.W.  
WASHINGTON, DC 20005  
202-408-4000

Additionally, in accordance with the present invention, a data processing system for requesting a digital certificate from a certificate authority and archiving an encryption key outside of the certificate authority is provided that comprises a memory having program instructions and a processor. A data processing system for requesting a digital certificate from a certificate authority and archiving an encryption key outside of the certificate authority. The processor is configured to execute the program instructions to receive a request from a user for a digital certificate, and receive an indication of proof of archival of the user's encryption key associated with the request, wherein the user's encryption key is archived under control of an entity other than the certificate authority.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an embodiment of the invention and, together with the description, serve to explain the advantages and principles of the invention.

Figure 1 shows an exemplary computer system suitable for use in accordance with the present invention;

Figure 2 illustrates an exemplary digital certificate management system having a data recovery manager controlled by a certificate authority;

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

Figure 3 depicts an exemplary digital certificate management system having a data recovery manager outside of the control of a certificate authority, and sending a signed proof of archival token in accordance with the present invention; and

Figures 4A-4C are flowcharts depicting steps for providing proof of archival of a private key in a digital certificate management system having a data recovery manager outside of the control of a certificate authority in accordance with the present invention.

### DETAILED DESCRIPTION

Methods and systems in accordance with the present invention allow users' private keys corresponding to their digital certificates to be stored and archived outside of the control of a Certificate Authority. A CA may have a policy that a user's private key must be archived in order to receive a digital certificate upon a registration request from the user. Typically, the CA knows that the user's private key is archived because it implemented the archival of the key, for example, on a data recovery manager and associated internal database that the CA controls.

However, methods and systems in accordance with the present invention allow for the enforcement of such a policy, *i.e.*, requiring archival of a user's private key to get a certificate, while allowing the archival of the private keys to be outside of the control of the CA. They allow for the data recovery manager and a database of archived keys to be controlled by other entities, including the user or client, for example. In that way, the user or client can keep control over its private keys and reduces the chance that they will be compromised by someone associated with the CA.

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000



In methods and systems in accordance with the present invention, when a registration manager receives a request for a digital certificate from a user and client, it securely sends the user's private key to a data recovery manager that is not controlled by a certificate authority for storage and archiving. In one implementation consistent with principles related to the present invention, the data recovery manager and it's associated database are controlled by the user or user's organization.

The data recovery manager then encrypts the user's private key using the data recovery manager's storage key and stores it in its associated database for archiving. The data recovery manager's private storage key (known only by the data recovery manager or possibly by recovery agents), is needed to decrypt the user's private key from the database. The data recovery manager then creates a "proof of archival" token ("POA") indicating that the associated user's private key has been archived. The data recovery manager digitally signs the proof of archival token with its data recovery manager transport key for secure transmission and sends the signed proof of archival token to the registration manager.

The registration manager verifies, using the data recovery manager's transport public key, that the proof of archival token was actually received from the data recovery manager. If so, the registration manager sends the client's request for a digital certificate to the CA which returns a digital certificate for the user. Because the registration manager received verification that the data recovery manager archived the user's private key, the CA knows that the user's private key is archived.

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N.W.  
WASHINGTON, DC 20005  
202-408-4000

In one implementation consistent with principles related to the present invention, the proof of archival token is sent with the request to the CA.

If the proof of archival token was not verified to have been signed by the data recovery manager, no proof of archival token is returned, and the certificate request may be denied.

### Computer Architecture

Figure 1 is a block diagram that illustrates a computer system 100 in which methods and systems consistent with the invention may be implemented. Computer system 100 may represent any of the computers discussed herein (e.g., client, registration manager, data recovery manager, database, certificate authority, certificate manager) and is not limited to a client or server or otherwise, and embodiments in accordance with the present invention are not limited to any specific combination of hardware and/or software. Any of the components discussed may be hardware or software components.

Computer system 100 includes a bus 102 or other communication mechanism for communicating information, and a processor 104 coupled with bus 102 for processing information. Computer system 100 also includes a main memory 106, such as a random access memory ("RAM") or other dynamic storage device, coupled to bus 102 for storing information and instructions to be executed by processor 104. Main memory 106 may store a proof of archival token 132 which is described below. Computer system 100 further includes a read only memory ("ROM") 108 or other static storage device coupled to bus 102 for storing static information and instructions for processor 104. A storage device 110, such as a

magnetic disk or optical disk, is provided and coupled to bus 102 for storing information and instructions. The storage device 110 may also store archived private keys discussed below and may also represent the data recovery manager's database also described below.

5 Computer system 100 may be coupled via bus 102 to a display 112, such as a cathode ray tube ("CRT"), for displaying information to a computer user. An input device 114, such as a keyboard, is coupled to bus 102 for communicating information and commands to processor 104. Another type of user input device is cursor control 116, such as a mouse, for communicating with processor 104 and for  
10 controlling cursor movement on display 112.

Computer system 100 also includes a communication interface 118 coupled to bus 102. Communication interface 118 provides a two-way data communication coupling to a network link 120 that may be connected to local network 122. For example, communication interface 118 may be a modem, for example, to provide a data communication connection. As another example, communication interface 118  
15 may be a local area network ("LAN") card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, communication interface 118 sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.  
20

Network link 120 typically provides data communication through one or more networks to other data devices. For example, network link 120 may provide a connection through local network 122 to a host computer 124 or to a wide area

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

network ("WAN") such as the Internet 128. Local network 122 and Internet 128 both use electric, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on network link 120 and through communication interface 118, which carry the digital data to and from computer system 100, are exemplary forms of carrier waves transporting the information.

Figure 2 shows an exemplary digital certificate management system having a data recovery manager controlled by a certificate authority 208. In this system, a user 202 sends a request via a client 204 for a digital certificate from a CA 208. The client 204 generates a key pair, a public key and a private key, for the user 202. If the user 202 signs a digital message with the private key known only to the user, the public key can be used by an entity to verify that it was in fact the user who signed it.

The client 204 forwards the request, which includes the private key and the public key, to the registration manager 206. The registration manager 206 performs local (organizational) policy checking, and then forwards the request including the user's private key, which is encrypted by the transport certificate, to the CA 208. The certificate manager 210 of the CA 208 handles the incoming request by checking the CA's local policies. If key archival is required by the CA's local policies, then it also sends the user's private key to the data recovery manager 212 for archiving in the associated internal database A14. In this exemplary system, the data recovery manager 212 and key archival database are located on and controlled by the CA 208. Since the CA 208 performed the archiving, it can ensure that a user's private key is archived before issuing a digital certificate.

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

Figure 3 depicts an exemplary digital certificate management system having a data recovery manager 212 outside of the control of a certificate authority 208 that sends a signed proof of archival token 132 in accordance with features associated with the present invention. In contrast to the system of Figure 2, the data recovery manager 212 and associated key archival database are not within control of the CA 208. In one implementation consistent with principles related to the present invention, the data recovery manager 212 and associated key archival database are under the control of the user 202.

Figures 4A, 4B and 4C are flowcharts showing proof of archival of a private key in a digital certificate management system having a data recovery manager outside of the control of a certificate authority 208 in accordance with the present invention, and they will be discussed in conjunction with Figure 3 to illustrate an implementation in accordance with the present invention. First, a user 202 accesses a client 204 capable of generating dual key pairs for encryption for other users, and the client generates the keys (step 402). This client 204 may access a certificate enrollment form served by the registration manager 206 that is used to provide information for obtaining a digital certificate from the CA 208. The user 202 fills in the information and submits the request through the client 204.

In one implementation consistent with principles related to the present invention, the client 204 automatically securely provides the user's private key to the registration manager 206 for archival. In another implementation consistent with principles related to the present invention, the user's request contains a request for

key archival, and the registration manager 206 detects the key archival option in the user's request and asks the client 204 for the user's encryption private key.

The data recovery manager 212 has a transport certificate used to securely transport information to the data recovery manager, so that only the data recovery manager may decrypt it. The public key of the transport certificate may be used to encrypt information to be sent to the data recovery manager 212. A copy of the transport certificate may be embedded in the certificate enrollment form transmitted by the registration manager 206.

The client 204 encrypts the user's private key with the transport public key from the data recovery manager's transport certificate for secure transmission (step 404). The client 204 sends the certificate request, which includes the user's public key and transport-encrypted private key, to the registration manager 206 (step 406). Upon receiving the transport-encrypted key from the client 204 (step 408), the registration manager 206 sends it to the data recovery manager 212 for storage, along with other information including the user's public key (step 410). Then, the registration manager 206 waits for verification from the data recovery manager 212 that the user's private key has been received and stored and that it corresponds to the user's public encryption key.

Upon receipt of the transport-encrypted key from the registration manager 206, the data recovery manager 212 decrypts it with the data recovery manager's transport private key that corresponds to the transport public key in its transport certificate (step 412). The data recovery manager 212 then checks the decrypted user's private key with the user's public key to verify that it originated from the user

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

202 (step 414). If it does not match with the user's public key, notification is sent to the registration manager 206 and registration is denied (step 416). In this case, no proof of archival token 132 is returned.

If the private encryption key corresponds to the user's public encryption key, the data recovery manager 212 encrypts it again with its public storage key before storing it in its internal database for secure storage (step 418). It then stores it in an associated database which may be internal to the data recovery manager 212 (step 420). In one implementation consistent with principles related to the present invention, the data recovery manager's storage key is not exposed to any other entity. In most instances, the data recovery manager's private storage key may be used to decrypt the user's archived private key from the internal database.

In one implementation consistent with principles related to the present invention, several recovery agents may be used to recover the encrypted archived key and may each have a piece of the private storage key so that no one agent may decrypt it. In this case, for added security, multiple recovery agents are required to decrypt a stored private key.

In another implementation consistent with principles related to the present invention, the recovery agents' pieces of the storage private key are protected by passwords.

Once the user's private encryption key has been successfully stored, the data recovery manager 212 creates a proof of archival token 132 (step 422). The proof of archival token 132 may be a portion of software defined, for example, in the Java<sup>TM</sup> programming language. An exemplary proof of archival token 132 is shown:

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

ProofOfArchival ::= SEQUENCE {  
     tbsProofOfArchival    TBSPProofOfArchival,  
     signatureAlgorithm    AlgorithmIdentifier,  
     signatureValue        BIT STRING  
   }

TBSPProofOfArchival ::= SEQUENCE {  
     version [0] Version DEFAULT v1,  
     signature AlgorithmIdentifier,  
     serialNumber INTEGER,  
     subjectName Name,  
     issuerName Name,  
     subjectPublicKeyInfo subjectPublicKeyInfo,  
     dateOfArchival Time,  
     extensions [1] Extensions OPTIONAL  
   }

The following are definitions for portions of the above code:

Name, Time, Extensions are defined in the X.501 standard.

Version - version of the implementation of the proof of archival.

Serial Number - Unique ID for the proof of archival.

Subject Name - The name of the owner of the archived key.

Issuer Name - The name of the data recovery manager 212.

Date of Archival - specifies the date when the key is archived.

Extensions - for optional expansion.



Subject Public Key Info - The corresponding public key for the private key that is being archived.

Signature - The algorithm identifier for the algorithm used by the data recovery manager 212 to sign the proof of archival.

5           The data recovery manager 212 uses the transport private key to sign the proof of archival token 132 which confirms that the user's key has been successfully stored (step 424). The data recovery manager 212 then sends the signed proof of archival token 132 to the registration manager 206 (step 426).

10           The registration manager 206 receives and verifies the signed token 132 by using the transport public key to verify that the proof of archival token originated from the data recovery manager 212 (step 428). If it is valid and determined to have originated from the data recovery manager 212 (step 430), the registration manager 206 then sends the certificate request to the certificate manager 210 for issuance of a certificate (step 434). In one implementation consistent with principles related to  
15           the present invention, the proof of archival token 132 is sent to the certificate manager 210 with the request. If it is not valid, registration is denied (step 432).

20           The certificate manager 210 formulates a certificate for the user 202 and returns it to the registration manager 206 (step 436). In one implementation, two certificates are returned, one each for signing and encryption key pairs. The registration manager 206 forwards the certificate(s) to the client 204 which, in turn, returns it to the user 202 (step 438).

LAW OFFICES

FINNEGAN, HENDERSON,  
FARABOW, GARRETT,  
& DUNNER, L.L.P.  
1300 I STREET, N. W.  
WASHINGTON, DC 20005  
202-408-4000

In one implementation consistent with the principles related to the present invention, the three subsystems (registration manager 206, data recovery manager 212 and certificate manager 210) subject the request to configured policy rules that govern the request at appropriate stages. If the request fails to meet any of the policy rules, the subsystem may reject the request.

5

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. Furthermore implementations consistent with the present invention may be implemented by computer programs that may be stored on computer-readable media. It is intended that the specification and examples be considered as exemplary, with a true scope and spirit of the invention being indicated by the following claims.

10

11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000  
1001  
1002  
1003  
1004  
1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014  
1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032  
1033  
1034  
1035  
1036  
1037  
1038  
1039  
1040  
1041  
1042  
1043  
1044  
1045  
1046  
1047  
1048  
1049  
1050  
1051  
1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272  
1273  
1274  
1275  
1276  
1277  
1278  
1279  
1280  
1281  
1282  
1283  
1284  
1285  
1286  
1287  
1288  
1289  
1290  
1291  
1292  
1293  
1294  
1295  
1296  
1297  
1298  
1299  
1300  
1301  
1302  
1303  
1304  
1305  
1306  
1307  
1308  
1309  
1310  
1311  
1312  
1313  
1314  
1315  
1316  
1317  
1318  
1319  
1320  
1321  
1322  
1323  
1324  
1325  
1326  
1327  
1328  
1329  
1330  
1331  
1332  
1333  
1334  
1335  
1336  
1337  
1338  
1339  
1340  
1341  
1342  
1343  
1344  
1345  
1346  
1347  
1348  
1349  
1350  
1351  
1352  
1353  
1354  
1355  
1356  
1357  
1358  
1359  
1360  
1361  
1362  
1363  
1364  
1365  
1366  
1367  
1368  
1369  
1370  
1371  
1372  
1373  
1374  
1375  
1376  
1377  
1378  
1379  
1380  
1381  
1382  
1383  
1384  
1385  
1386  
1387  
1388  
1389  
1390  
1391  
1392  
1393  
1394  
1395  
1396  
1397  
1398  
1399  
1400  
1401  
1402  
1403  
1404  
1405  
1406  
1407  
1408  
1409  
1410  
1411  
1412  
1413  
1414  
1415  
1416  
1417  
1418  
1419  
1420  
1421  
1422  
1423  
1424  
1425  
1426  
1427  
1428  
1429  
1430  
1431  
1432  
1433  
1434  
1435  
1436  
1437  
1438  
1439  
1440  
1441  
1442  
1443  
1444  
1445  
1446  
1447  
1448  
1449  
1450  
1451  
1452  
1453  
1454  
1455  
1456  
1457  
1458  
1459  
1460  
1461  
1462  
1463  
1464  
1465  
1466  
1467  
1468  
1469  
1470  
1471  
1472  
1473  
1474  
1475  
1476  
1477  
1478  
1479  
1480  
1481  
1482  
1483  
1484  
1485  
1486  
1487  
1488  
1489  
1490  
1491  
1492  
1493  
1494  
1495  
1496  
1497  
1498  
1499  
1500  
1501  
1502  
1503  
1504  
1505  
1506  
1507  
1508  
1509  
1510  
1511  
1512  
1513  
1514  
1515  
1516  
1517  
1518  
1519  
1520  
1521  
1522  
1523  
1524  
1525  
1526  
1527  
1528  
1529  
1530  
1531  
1532  
1533  
1534  
1535  
1536  
1537  
1538  
1539  
1540  
1541  
1542  
1543  
1544  
1545  
1546  
1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554  
1555  
1556  
1557  
1558  
1559  
1560  
1561  
1562  
1563  
1564  
1565  
1566  
1567  
1568  
1569  
1570  
1571  
1572  
1573  
1574  
1575  
1576  
1577  
1578  
1579  
1580  
1581  
1582  
1583  
1584  
1585  
1586  
1587  
1588  
1589  
1590  
1591  
1592  
1593  
1594  
1595  
1596  
1597  
1598  
1599  
1600  
1601  
1602  
1603  
1604  
1605  
1606  
1607  
1608  
1609  
1610  
1611  
1612  
1613  
1614  
1615  
1616  
1617  
1618  
1619  
1620  
1621  
1622  
1623  
1624  
1625  
1626  
1627  
1628  
1629  
1630  
1631  
1632  
1633  
1634  
1635  
1636  
1637  
1638  
1639  
1640  
1641  
1642  
1643  
1644  
1645  
1646  
1647  
1648  
1649  
1650  
1651  
1652  
1653  
1654  
1655  
1656  
1657  
1658  
1659  
1660  
1661  
1662  
1663  
1664  
1665  
1666  
1667  
1668  
1669  
1670  
1671  
1672  
1673  
1674  
1675  
1676  
1677  
1678  
1679  
1680  
1681  
1682  
1683  
1684  
1685  
1686  
1687  
1688  
1689  
1690  
1691  
1692  
1693  
1694  
1695  
1696  
1697  
1698  
1699  
1700  
1701  
1702  
1703  
1704  
1705  
1706  
1707  
1708  
1709  
1710  
1711  
1712  
1713  
1714  
1715  
1716  
1717  
1718  
1719  
1720  
1721  
1722  
1723  
1724  
1725  
1726  
1727  
1728  
1729  
1730  
1731  
1732  
1733  
1734  
1735  
1736  
1737  
1738  
1739  
1740  
1741  
1742  
1743  
1744  
1745  
1746  
1747  
1748  
1749  
1750  
1751  
1752  
1753  
1754  
1755  
1756  
1757  
1758  
1759  
1760  
1761  
1762  
1763  
1764  
1765  
1766  
1767  
1768  
1769  
1770  
1771  
1772  
1773  
1774  
1775  
1776  
1777  
1778  
1779  
1780  
1781  
1782  
1783  
1784  
1785  
1786  
1787  
1788  
1789  
1790  
1791  
1792  
1793  
1794  
1795  
1796  
1797  
1798  
1799  
1800  
1801  
1802  
1803  
1804  
1805  
1806  
1807  
1808  
1809  
1810  
1811  
1812  
1813  
1814  
1815  
1816  
1817  
1818  
1819  
1820  
1821  
1822  
1823  
1824  
1825  
1826  
1827  
1828  
1829  
1830  
1831  
1832  
1833  
1834  
1835  
1836  
1837  
1838  
1839  
1840  
1841  
1842  
1843  
1844  
1845  
1846  
1847  
1848  
1849  
1850  
1851  
1852  
1853  
1854  
1855  
1856  
1857  
1858  
1859  
1860  
1861  
1862  
1863  
1864  
1865  
1866  
1867  
1868  
1869  
1870  
1871  
1872  
1873  
1874  
1875  
1876  
1877  
1878  
1879  
1880  
1881  
1882  
1883  
1884  
1885  
1886  
1887  
1888  
1889  
1890  
1891  
1892  
1893  
1894  
1895  
1896  
1897  
1898  
1899  
1900  
1901  
1902  
1903  
1904  
1905  
1906  
1907  
1908  
1909  
1910  
1911  
1912  
1913  
1914  
1915  
1916  
1917  
1918  
1919  
1920  
1921  
1922  
1923  
1924  
1925  
1926  
1927  
1928  
1929  
1930  
1931  
1932  
1933  
1934  
1935  
1936  
1937  
1938  
1939  
1940  
1941  
1942  
1943  
1944  
1945  
1946  
1947  
1948  
1949  
1950  
1951  
1952  
1953  
1954  
1955  
1956  
1957  
1958  
1959  
1960  
1961  
1962  
1963  
1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025  
2026  
2027  
2028  
2029  
2030  
2031  
2032  
2033  
2034  
2035  
2036  
2037  
2038  
2039  
2040  
2041  
2042  
2043  
2044  
2045  
2046  
2047  
2048  
2049  
2050  
2051  
2052  
2053  
2054  
2055  
2056  
2057  
2058  
2059  
2060  
2061  
2062  
2063  
2064  
2065  
2066  
2067  
2068  
2069  
2070  
2071  
2072  
2073  
2074  
2075  
2076  
2077  
2078  
2079  
2080  
2081  
2082  
2083  
2084  
2085  
2086  
2087  
2088  
2089  
2090  
2091  
2092  
2093  
2094  
2095  
2096  
2097  
2098  
2099  
2100  
2101  
2102  
2103  
2104  
2105  
2106  
2107  
2108  
2109  
2110  
2111  
2112  
2113  
2114  
2115  
2116  
2117  
2118  
2119  
2120  
2121  
2122  
2123  
2124  
2125  
2126  
2127  
2128  
2129  
2130  
2131  
2132  
2133  
2134  
2135  
2136  
2137  
2138  
2139  
2140  
2141  
2142  
2143  
2144  
2145  
2146  
2147  
2148  
2149  
2150  
2151  
2152  
2153  
2154  
2155  
2156  
2157  
2158  
2159  
2160  
2161  
2162  
2163  
2164  
2165  
2166  
2167  
2168  
2169  
2170  
2171  
2172  
2173  
2174  
2175  
2176  
2177  
2178  
2179  
2180  
2181  
2182  
2183  
2184  
2185  
2186  
2187  
2188  
2189  
2190  
219